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A Guide to Explosives Firing

Michael G. Wolfson

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Michael G. Wolfson

Weapons Systems Division
Aeronautical and Maritime Research Laboratory

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ABSTRACT

This document is a guide to explosives firing using exploding bridgewire (EBW) detonators. It details the special equipment and procedures developed in the Weapons Systems Division, Maribyrnong and currently in use in the Division's firing chambers and at field test sites, and discusses the relative merits of electric detonators and EBW detonators. It serves as a useful guide and reference document to both Firing Officer trainers and trainees.

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Executive Summary

In January 1995 DSTO formed Weapons Systems Division, an amalgamation of Explosives Ordnance Division (EOD) and Guided Weapons Division (GWD). EOD operations were split between the Maribyrnong (MB) and Salisbury (SB) sites but following the formation of WSD the decision was made to consolidate all WSD activities at the Salisbury site by December 1997, necessitating the relocation of the Maribyrnong component to Salisbury. At present the Division's enclosed explosive test facilities (firing chambers) are all located at Maribyrnong and consequently the necessary knowledge and experience to operate such facilities and conduct explosive firings also reside at Maribyrnong. However firing chambers will be built at Salisbury as part of the relocation of Maribyrnong facilities.

The Officer-in-Charge (OIC) is responsible for the day-to-day operations of the firing chambers and for many years has had sole responsibility for training those people who conduct explosive firings, namely Firing Officers. To ensure continuity of firing operations upon relocation to Salisbury, and therefore minimum disruption to a wide range of WSD Tasks, Salisbury staff are being trained now as Firing Officers. Furthermore, it is important that future Firing Officer trainers be properly briefed.

It is the purpose of this document to help facilitate the transfer of technology from Maribynong to Salisbury. It provides a guide to explosives firing using exploding bridgewire (EBW) detonators and details the special equipment and procedures developed in WSD(MB) and currently in use in the Division's firing chambers and at field test sites such as the Army's Proof and Experimental Establishment at Graytown, Victoria. It also discusses the relative merits of electric and EBW detonators and includes sections on Standing Safety Orders, Operating Procedures and good practices. It is intended to provide all DSTO personnel involved with explosives firing, particularly Firing Officer trainers and trainees and those previously unfamiliar with this work, with a useful guide and reference document.

Contents

1. Introduction

The main purpose of this document is to help facilitate the transfer of technology from the Weapons Systems Division (WSD) Maribyrnong (MB) site in Victoria to the WSD Salisbury (SB) site in South Australia, necessitated by the decision to consolidate all the Division's activities at Salisbury by December 1997 [1]. At present the Division's enclosed explosive test facilities (firing chambers) are all at Maribynong and consequently the personnel with the necessary knowledge and experience to operate such facilities and conduct explosives firings also reside at Maribyrnong. Firing chambers will be built at Salisbury as part of the relocation of Maribyrnong facilities.

It is very unlikely that the current Scientist-in-Charge (SIC) or the long serving Officer-in-Charge (OIC) of the Maribyrnong firing chambers will be relocating to Salisbury. The OIC (the author) is responsible for the day-to-day operations of the firing chambers and for many years has had the sole responsibility for training those people who conduct explosives firings, namely Firing Officers. In addition Firing Officers from the Ship Structures and Materials Division (SSMD) at Maribyrnong and Australian Defence Force (ADF) personnel have been trained in the safe and proper use of exploding bridgewire (EBW) detonators and the associated firing equipment. To ensure continuity of expertise in firing operations and safety, appropriate Salisbury staff are being trained now as Firing Officers. Furthermore, it is important that future Firing Officer trainers at both Maribyrnong and Salisbury be selected and properly briefed; this document is meant to provide guidance to both trainees and future trainers.

To be a safe and effective Firing Officer requires training in both the theory and practice of explosives firing. A range of attributes is required including knowledge and experience of explosives and explosives handling, an appreciation of general occupational health and safety issues and sound instrumentation skills. This document provides an introduction to the theory of explosives firing and outlines the procedures developed over many years and currently in use in WSD(MB). It is recommended that the information set out in this document be presented to trainees by an experienced Firing Officer prior to commencing on-the-job training; Appendix A (A.1-A.22) is a compilation of visual aids which can be presented as overhead transparencies as part of Firing Officer training. On-the-job training should build on the information presented here and should commence as soon as possible after presentation.

2. Basic Requirements

Firstly, we will look at what is required to conduct an electrically initiated explosives firing. Basically, we need the following (Appendix A.1): An **Explosive Charge,** maybe an **Explosive Booster,** a **Detonator** and some **Firing Equipment.**

This document only deals with electrically initiated explosives firings and concentrates on the **Detonator** and the **Firing Equipment**, including guidelines and procedures for their safe and effective use.

Although outside the scope of this document, it is important that the Firing Officer be aware of the AMRL Explosives Regulations [2] and familiar with the explosive materials to be fired, particularly with any special hazards or precautions that need to be taken, e.g. special precautions need to be taken with lead sheathed explosives as the detonation products of these materials present a toxic hazard. If not provided at the planning stage such information should be sought from the requesting officer or Task Manager prior to firing. A knowledge of explosive boosters and their application would also be an advantage as the Firing Officer's advice regarding boosters is often sought.

3. Choosing a Detonator

3.1 Types of Available Detonators

There are two main types of detonators available for our use, namely **Electric Detonators** (Appendix A.2), typified by the No. 8 and L2A1 detonators, and **EBW Detonators** (Appendix A.3), typified by the RP 501 detonator (Appendix A.4) manufactured by Reynolds Industries Systems, Incorporated (RISI). The main differences between these two detonator types are summarised in Appendix A.5 and described below.

3.1.1 Comparison Between Electric and EBW Detonators

Electric detonators [3] contain primary explosives (primaries), e.g. lead azide and lead styphnate whereas EBW detonators [4] contain only secondary explosives (secondaries), e.g. pentaerythritol tetranitrate (PETN) and cyclotrimethylenetri-nitramine (RDX). Fillings consisting of secondaries are less sensitive than primaries to most initiation stimuli and unlike primaries will not readily detonate when subjected to spark, flame or hot wire. In fact, secondary fillings generally require special conditions to initiate detonation, viz. a high energy shockwave.

The initiation of an electric detonator (Appendix A.2) is a thermal process and is achieved by electrical heating of the bridgewire in the fusehead to the ignition temperature of the flashing mixture (282°C for lead styphnate); the bridgewire resistance is typically 1 ohm. To reach the ignition temperature only requires a relatively low voltage, low current DC power source (Appendix A.6) such as a torch battery, although in practice a low voltage capacitor discharge firing circuit is commonly used. Furthermore, special precautions must be exercised when connecting an electric detonator to a firing cable in conditions where electrostatic charges can be generated by personnel or equipment, or a very strong electromagnetic field may exist

(e.g. in the vicinity of radar, radio and television transmitters), as the detonator lead/firing cable, acting as an antenna, may pick up sufficient radiated power to fire the detonator. Consequently, it is a requirement that the detonator be connected to the firing cable before attachment to the explosive charge; inadvertent firing of the detonator alone with personnel present is not a catastrophic event whereas an inadvertent explosion of the main charge is. Galvanic electricity, stray currents and lightning are other energy sources that under certain conditions can also fire an electric detonator.

The bursting time (or functioning time) of an electric detonator (Appendix A.6) is defined as the time from first application of current to the detonator exploding and even for an "instantaneous detonator" it is relatively long and variable (50 μs - 5 ms). The bursting time will be influenced by manufacturing variations in the fusehead, the type of firing circuit employed and the length (electrical resistance) of the firing cable.

The initiation of an EBW detonator (Appendices A.3 and A.4) requires the rapid application of a high energy electrical discharge (Appendix A.7) across the bridgewire, causing it to explode and a shockwave to be generated which initiates the pressed low density PETN in contact with the bridgewire; the bridgewire resistance is typically 0.3 ohm. The shockwave from the detonating low density PETN then initiates detonation in the pressed high density PETN or RDX output explosive.

The basic EBW detonator firing circuit (Appendix A.7) consists of a power supply to charge the firing capacitor C through the charging resistor R, and a triggered spark gap switch to discharge the firing capacitor across the bridgewire via the transmission line (firing lead). To ensure a sufficiently rapid discharge for proper functioning of the detonator it is very important that the total circuit inductance be kept low. In practice this limits the firing cable length, under ideal conditions, to about 30 m. In the WSD firing circuit a 1 μF firing capacitor is charged to 3.0 kV and the measured circuit inductance (for a 5 m firing cable) is about 2 μH.

An insight into the functioning of an EBW detonator can be obtained from the voltage-time or current-time characteristics of the bridgewire during firing. A typical voltage-time trace obtained from firing an EBW detonator of WSD manufacture using WSD firing equipment is the upper trace shown in Appendix A.8. The traces both start at the instant the firing circuit receives a trigger pulse and after an inherent trigger delay of about 2.3 μs the voltage rises from zero to the peak voltage in about 0.6 μs. This time we refer to as the Peak Voltage Time (PVT) which is approximately the time to bridgewire burst. The spike on the lower trace was generated by an ionisation probe [5] placed in contact with the output end of the detonator to detect the arrival of the detonation wave. Hence the Functioning Time (FT) of the detonator can be obtained, this being the time from current zero to detonation out (about 3.3 μs in the example). The time taken by the explosive reaction is referred to as the Explosive Time (ET) and is derived by subtracting the PVT from the FT. When proof firing EBW detonators, the shape of the voltage-time trace and the PVT, FT and ET values can be invaluable in detecting and diagnosing problems with the detonator or firing circuit.

From a user perspective, for example when deciding on firing delays, the Total Operating Time (TOT) of the detonator is the time that needs to be known. This is the time from the input of a trigger pulse to the firing unit to detonation out from the detonator; about 5.6 μs from the trace in Appendix A.8. A feature of EBW detonators is their short and very reproducible functioning times, making possible accurate synchronisation with other events and instrumentation such as synchronous rotating mirror ultra high-speed cameras.

3.2 Reasons For Choosing EBW Detonators

At WSD(MB) we standardised many years ago on the use of EBW detonators, except in special circumstances. This decision was made after weighing up the advantages and disadvantages outlined in Appendix A.9 and summarised below.

EBW detonators are inherently safer than electric detonators as they contain only secondary explosives: they are not easy to initiate, do not present an electrostatic or RF hazard and are not particularly sensitive to rough handling (but as with all explosive devices rough handling should be avoided). In addition, because of their special initiation requirements, EBW detonators may safely be attached to an explosive charge before connecting to the firing cable if required; this can be very important with many experimental explosive assemblies.

EBW detonators have short functioning times (typically 2 - 5 μs) which are very reproducible (typically ± 0.1 μs), making them ideal for synchronisation with other events or instrumentation.

For underwater firings, waterproof EBW detonators are available.

EBW detonators however, do require special firing equipment, including a Firing Unit which must be located near the detonator to satisfy the requirement for low circuit inductance. Furthermore, EBW detonators are not manufactured in Australia and are relatively expensive ($10 - $50 each depending on specification and quantity ordered) compared to electric detonators ($2 each).

After many years of experience there is no doubt that the advantages of EBW detonators far outweigh the disadvantages and the decision to use them in place of electric detonators whenever possible has been vindicated. The blast and moisture resistant Firing Unit, designed and constructed in-house following the decision, has proved very successful and its proximity to the explosion site is now of little concern. The ability to attach the detonator to the main charge early in the setup phase has proved to be an important feature while a quick analysis of the cost factor shows that the cost of an EBW detonator is very small when compared with the overall cost of most experimental explosive firings and therefore should also be of little concern.

4. Firing Equipment

4.1 General Description

The firing system in common use in WSD was designed and constructed in-house and comprises a **Control Unit**, a **Firing Unit** and a **Safe/Arm Key**, which must all have the same identification number, and **Interconnecting Cables**. A photograph of this firing system is shown in Appendix A.10. Also in use in SSMD is a commercial firing system [4] manufactured and supplied by RISI which is mainly used at the SSMD Underwater Test Facility, Epping, Victoria. Although the principles of operation of the WSD and RISI systems are similar there are some differences. This document will concentrate on the WSD system. (Before using the RISI system it would be necessary for an inexperienced Firing Officer to read the Operating Manual and obtain additional training from a suitably experienced Firing Officer).

There are two versions of the Control Unit: one is a single channel unit designed for field use (Appendix A.11) and the other is a three channel unit designed for use in the firing chambers. However, they both have the same basic features described below. Firing Units are all of the same design and are blast and moisture resistant (Appendix A.12). The functions of the Control Unit and Firing Unit are summarised in Appendices A.13 and A.14 and further described below. Their circuit diagrams are shown in Appendices A.15 and A.16, respectively.

4.2 Control Unit

4.2.1 Safety

The Control Unit (Appendices A.13 and A.15) is connected to the Firing Unit by a five-core control cable and sometimes (see 4.2.5) a coaxial trigger cable. **The firing system is safe until it is armed by inserting the Safe/Arm Key in the Control Unit key switch and turning it clockwise.** Therefore as long as the Firing Officer has possession of the Safe/Arm key the Firing Unit cannot be energised as it receives its power from the Control Unit.

4.2.2 Power Requirements

The Control Unit (Appendix A.15) can be powered by the 240 VAC mains supply or a suitable generator, and selected Control Units can be powered by a 12 V battery (e.g. a car battery). The Control Unit itself supplies approximately 240 VAC to the Firing Unit via the control cable. The actual voltage (Input Volts) being supplied to the Firing Unit is displayed on a voltmeter and can be adjusted by using a variac; both the voltmeter and variac control knob are located on the front panel (Appendix A.11). The voltage adjustment provides a means of compensating for the voltage drop over control cables of different lengths. **Note: When adjusting the input voltage it is important that the**

Firing Officer observes the Extra High Tension (EHT) Voltmeter (see 4.2.4) which monitors the firing voltage, to ensure the safe maximum firing voltage of 3 kV(see 4.3.2) is not exceeded.

4.2.3 Ohmmeter

The Control Unit (Appendix A.11) contains a safety ohmmeter circuit powered by two 1.5 V AA cells (accessible from the front panel) which measures the total resistance of the firing circuit (including cable resistance, etc.) and displays the reading on a panel meter (labelled "Ignition Circuit Impedance"). As the cable resistance is generally large (10 - 50 ohms) compared to the detonator bridgewire resistance (0.3 ohm), and contact resistance in connectors and switches is significant and variable, **this can only be considered as a continuity test.** If after setting up a firing system and before connecting the detonator, a short circuit test followed by an open circuit test is conducted, the continuity test (with the detonator connected) is not only useful but important. For example, it is particularly important as a diagnostic tool in the event of a suspected misfire; after an unsuccessful attempt to fire, an open circuit is indicative of a misfire whereas a low resistance reading indicates that the bridgewire is still intact and it is not a misfire but an "instrumentation fault".

Warning: A general purpose ohmmeter or multimeter must never be used for measuring the bridgewire resistance of any detonator, particularly electric detonators. In some cases, the current produced by such instruments would be sufficient to initiate an electric detonator. While the current would not initiate an EBW detonator, it is possible that the bridgewire would be fused, thus rendering the detonator useless.

4.2.4 EHT Voltmeter

The EHT voltmeter located on the front panel of the Control Unit (Appendix A.11) allows the DC voltage across the firing capacitor (the firing voltage) to be monitored; the firing capacitor and a voltage divider for the voltmeter are located in the Firing Unit. The recommended firing voltage is 3.0 kV, however as it is important not to exceed this voltage (see 4.3.2) it is acceptable to fire at a slightly lower voltage, say 2.8 kV to 2.9 kV.

To ensure that the voltage indicated on the EHT voltmeter corresponds to the voltage across the firing capacitor, it is important that the Firing Unit and Control Unit have the same identification number. This is normal practice when using a single channel Control Unit as matching units (keyed-alike) are also required to permit arming of the firing system. Similarly when using a three channel Control Unit, whether it be to control one, two or three Firing Units, the matching Firing Unit must always be used as one of the Firing Units. When adjusting the firing voltage with two or three Firing Units in use, it may not be possible to get an accurate indication of the firing voltage on all EHT voltmeters. The firing can proceed provided the correct firing voltage is

indicated on the EHT voltmeter for the matching Firing Unit and the voltage(s) indicated for the other(s) exceeds 2.5 kV.

4.2.5 Trigger Pulse

A +150 V pulse is produced at the Trigger Output BNC connector (Appendix A.11) of an armed Control Unit when the firing switch is pressed or when an external switch closure is provided via one of the External Switch connectors on the front panel, e.g. from a high-speed camera. The trigger pulse can be used to directly trigger the Firing Unit via a coaxial cable or to trigger other instrumentation such as a sequencer or delay pulse generator which in turn trigger the Firing Unit (> +55 V needed). **After triggering, further trigger pulses are inhibited until the circuit is reset by switching the Control Unit off.**

As a precaution against inadvertent triggering of the Firing Unit, when performing trigger tests using this output that do not involve the Firing Unit, the control cable should first be disconnected from the Control Unit.

4.3 Firing Unit

4.3.1 Safety

The Firing Unit (Appendices A.14 and A.16) is connected to the Control Unit by the five-core control cable and to a suitable trigger pulse source (e.g. Control Unit, sequencer or delay pulse generator) via a coaxial cable. The trigger cable is connected to either one of the parallel wired BNC connectors located on the recessed front panel of the Firing Unit (Appendix A.12). The Firing Unit also contains a Safe/Arm key switch, keyed-alike with the Control Unit switch. **When the key is inserted in the Firing Unit and turned clockwise to the safe position the firing capacitor is shorted and the firing lead isolated (internally) from the firing circuit.** This duplicates the safety functions provided by the safe/arm relay within the Firing Unit. **To arm the Firing Unit the safe/arm relay must be energised from the Control Unit and this can only be done by using the safe/arm key which is under the direct control of the Firing Officer.**

The coaxial firing cable is plugged into the Type C BNC connector located on the recessed front panel of the Firing Unit (Appendix A.12) and a twin flex firing lead is connected to the other end of the coaxial cable. Before connecting the firing lead or detonator to the Firing Unit, the safe/arm key must be in the Firing Unit in the safe position. **After connecting the detonator, the firing key is removed by the Firing Officer as the same key is required to activate the Control Unit. Until the Control Unit is activated the Firing Unit contains no stored energy.**

4.3.2 Other Firing Unit Functions

The Firing Unit contains a 1 μF capacitor for firing pulse generation, namely the firing capacitor. The 240 VAC supply from the Control Unit is stepped up and rectified to approximately 3 kV for charging the firing capacitor. **When charging the firing capacitor it is important not to exceed 3.0 kV as the triggered spark gap switch in the firing circuit has a nominal static breakdown voltage of 3.3 kV. Reaching the static breakdown voltage would cause the Firing Unit to self-trigger and the detonator to fire.** This occurrence would not present a safety hazard (as all personnel would be at a safe location prior to arming) but it could result in an expensive premature firing.

The Firing Unit also contains an SCR trigger circuit which is fired by a suitable trigger pulse (> +55 V) and this in turn fires the triggered spark gap via a pulse transformer, discharging the stored energy from the firing capacitor across the EBW detonator through the firing cable.

5. Firing Chamber Operation at Maribyrnong

5.1 Equipment Layout

In the enclosed explosive test facilities (firing chambers), such as the Building 1076 2.25 kg Explosive Test Facility at Maribyrnong (Appendix A.17), the Control Unit is located in the Control Room and the Firing Unit is located in the Instrument Room in close proximity to the Firing Chamber so that the firing cable length can be kept to a minimum. Firing and Control Units are interconnected through appropriate patch panels.

Safety of firing operations is assured by the use of mechanical *Castell* interlocks which ensure that the Control Unit multicore control cable cannot be connected to the Firing Unit without using the *Castell* key which is only available when the firing chamber door is locked[1].

5.2 Standing Safety Orders

The operations of all firing chambers and explosives laboratories in WSD(MB) and at the SSMD Underwater Test Facility are governed by prescribed Standing Safety Orders (SSOs) and in addition there are Firing Procedures covering the activities at each facility. **It is a safety requirement that all people working in the firing chambers be**

[1] Similar mechanical interlocks are installed in all the Maribyrnong explosive test facilities, including the Ballistics Range, to provide primary safety for all electrically initiated firings and it is considered highly desirable that they be included in the design of any future enclosed firing facilities. A range of suitable interlocks is available from Fortress Security Pty. Ltd., Braeside, Victoria.

familiar with the relevant SSOs before commencing work; the Firing Officer must also be familiar with the Firing Procedures. Examples of an SSO and Firing Procedures can be found in Appendices B and C, respectively.

5.3 Operating Procedures

Before operations involving explosives may commence, the OIC must ensure that the proposed operations are in accord with established safety principles for the area, and that any instrumentation to be used within the firing chamber is provided with a means of isolation from electrical power, e.g. the safety key/plug on a Probe Power Supply (used to power ionisation probes) to ensure against the risk of electrical shock. The OIC must also be satisfied that the Firing Officer fully understands the nature of the proposed operations, the proper firing procedures and his/her responsibilities. The OIC will then issue the appropriate *Castell* key and checklist to the Firing Officer. The Firing Officer must retain possession of this *Castell* key at all times except when the interlocked door to the firing chamber is secured and in particular must check that the *Castell* key and any other isolating keys/plugs are in his/her possession before connecting the detonator to the firing lead.

5.4 Warning Signals

It is important that people within earshot be provided with some warning of impending explosions in the firing facilities. Firstly, the warning indicates that the explosion was planned and not accidental and therefore of no cause for concern. Secondly, it stops people from being startled and if necessary allows them to stop what they are doing until after the explosion. To cater for the situations where the warning signal is heard but not the explosion or the explosion is heard but not the warning signal, an all clear signal should also be provided.

There are common warning signals prescribed by the SSOs for all the Maribyrnong firing chambers, as follows: **At least 30 s before firing, a warning signal of 3 short blasts on the siren must be sounded. Immediately a firing is completed, an all clear signal of a 3 s blast on the siren must be sounded.**

5.5 Misfire Procedure

Because misfires are inevitable, there needs to be a misfire procedure at each firing facility. At Maribyrnong there is a common misfire procedure prescribed by the SSOs for all the firing chambers, as follows: **If a misfire occurs, the OIC must be notified and no personnel may enter or approach the firing chamber without his permission.** A period of 15 minutes must elapse before entering the firing chamber to investigate the cause of the misfire. In the case of initiation experiments, e.g. gap tests [6, 7], a

failure of the donor will constitute a misfire but a failure of the receptor charge alone will not.

5.6 Use of Electric Detonators

The firing chamber SSOs do not permit the use of electric detonators unless written approval is obtained from the SIC on each occasion. Before approval is given, the OIC and/or the requesting officer will complete a one page proforma seeking SIC approval to use electric detonators. The information provided is as follows: Firing Officer name, detonator type, a sketch of the experimental setup and the handling procedures to be used. If, after discussion with all concerned, the SIC is satisfied with the proposal, including why EBW detonators cannot be used, the proforma will be signed giving approval for a specified period of time. This process is designed to ensure that the interested parties give proper consideration to what is an inherently less safe, non-routine activity.

5.7 Use of Non-Electric Detonators

The firing chamber SSOs do not permit the use of non-electric detonators, e.g. stab initiators. On the rare occasions when the use of non-electric detonators cannot be avoided, e.g. the non-electric detonator is an integral part of a service store, then a Temporary SSO covering the special activity must be submitted for approval through the Explosives Safety Advisory Panel (ExSAP). The reasons why EBW detonators or even electric detonators cannot be used will need to be justified.

5.8 Disposal of Explosives Waste

Specific Instruction No. 2 on all SSOs gives directions on explosives waste disposal for the building, facility or laboratory in question. WSD(MB) Safety Digest No. 3 (Appendix D) provides more detailed guidance on the methods to be used for the disposal of the more common explosives and related wastes. In all explosive firing facilities where operations are governed by an SSO it is the responsibility of the Firing Officer to ensure the proper disposal of explosives waste generated as a result of charge preparation and/or firing.

Ideally, the likelihood of explosive waste being produced as a result of explosive firing should be considered prior to firing when planning the tests or experiments. In this way proper consideration can be given to the most appropriate methods of waste disposal and proper provisions, if not already in place, can be made. For example, in go/no-go tests such as shock sensitivity gap tests explosive waste can be expected; on the other hand explosive waste that may result from a misfire is unexpected. In any event it is important that the waste be separated into the approved waste categories (Appendix D) and placed in the appropriate waste bins, e.g. HE under water, rubbish

contaminated with explosives, metal contaminated with explosives, etc. Rubbish contaminated with explosives should only contain small quantities of explosive contaminants and must not contain visible lumps of explosive materials. Sometimes special disposal arrangements may need to be made, e.g. explosives confined in metal tubes require special treatment and must not be disposed of as metal contaminated with explosives.

Firing Officers are not expected to be experts in explosives waste disposal and when in doubt should seek advice from the OIC, SIC, relevant task manager, officer responsible for managing the waste collection service, officer requesting the work or the ExSAP.

6. Field Firing Systems

6.1 Layout of a Basic Field Firing System

Appendix A.18 is a schematic of a basic EBW field firing system. The Control Unit is located at the Firing Point, typically in an instrumentation van or container with appropriate blast and/or fragment protection and positioned some 100 m - 200 m from the charge at ground zero (GZ). The Firing Unit is located near GZ usually within 15 m of the explosive charge and fitted inside a blast box, often with additional sand-bags or steel plate protection.

6.2 Firing System With Additional Instrumentation

Appendix A.19 is a schematic of a typical firing system integrated with other instrumentation. It consists of a camera remote control, delay pulse generator (DPG), flashbulb firer, cathode ray oscilloscope (CRO) and an EBW Control Unit all located at the Firing Point, and the flashbulbs and EBW Firing Unit located near GZ. The high-speed camera might be located somewhere between GZ and the Firing Point. The firing sequence in this case is initiated externally as follows: After confirming instrumentation readiness, the Firing Officer arms the firing system and confirms its readiness, the high-speed camera is then started remotely and when it reaches its operating speed it triggers the DPG. The DPG first triggers the Flashbulb Firer which fires the flashbulbs, then 17 ms later triggers the Firing Unit and provides time zero correlating pulses for the camera and CRO.

In this example the Firing Officer would need to have a reasonable understanding of the total instrumentation system including the firing system. It would also be important for the Firing Officer to liaise closely with the instrumentation team, particularly the high-speed camera operator. Often various sections of the instrumentation team need to perform trigger tests, sometimes requiring inter-connecting cables to be temporarily disconnected. Such tests should be carried out under the guidance of the Firing Officer and always completed before the final full

system test and before connecting the detonator to the Firing Unit. From the time of arming the charge until it is fired the Firing Officer is in control of the firing including the associated instrumentation and personnel.

6.3 Safety Documentation

Field experiments are generally run in accordance with an approved Technical Instruction which has an Annex detailing the Firing Instructions, including arming, disarming and misfire procedures. It is important that the Firing Officer be consulted early in the planning process, along with the Task Manager, Trial OIC and instrumentation team, so that safe, workable procedures can be agreed for inclusion in the Technical Instruction. It should be noted that there needs to be special emphasis placed on procedures in field firing situations as there can generally be no interlocks, such as those used in enclosed firing facilities (see 5.1), due to the lack of suitable physical barriers enclosing the field test site. Consequently, the safety of firing explosive charges in the field relies heavily on the experience of the Firing Officer who is often placed under considerable pressure.

When conducting field experiments at some sites, such as the Army's Proof and Experimental Establishment, Graytown (PEEG), local rules require that the Firing Officer be a PEEG staff member. In such cases the AMRL officer responsible for firings is referred to as the Firing Liaison Officer and must liaise with the Firing Officer who has overall responsibility for safety at that site.

7. Good Practices

Some good practices for Firing Officers are listed in Appendix A.20 and further described below.

7.1 Firing Equipment

- For field firings, particularly at remote sites, the Firing Equipment should be fully tested before dispatch to the trial site and a spare set of Firing Equipment included. **Field repairs on Firing Equipment or any other "Explosives Safety Critical Equipment" should not be attempted except in extenuating circumstances and then only by a suitably qualified person.**

- The Firing Equipment should be tested with any other instrumentation with which it is required to interface, e.g. sequencers, high-speed cameras and electronic recording instruments, prior to any actual firing.

- A full functional test of the Firing Equipment should be carried out at least at the start of each firing day. Firing a small flashbulb is a cheap and easy method sometimes employed for testing the overall operation of the firing system. Because of the high-voltage hazard, this must only be done when personnel are clear of the firing cable and flashbulb. Furthermore, **it cannot be assumed that because a flashbulb fires successfully that a detonator would have fired** as flashbulbs require much less energy to function than a detonator. Testing the proper functioning of the firing circuit can only be achieved by firing an EBW detonator or by using a tester such as the RISI TA-10B Tester [3]. In either case, the firing circuit should include the actual firing cable to be used in the firing so that its integrity is also verified.

- After firing, the Firing Unit and connecting cables should be carefully examined for damage. This is particularly important when fragmenting rounds are being fired as cables may be cut or small metal fragments may lodge in the coaxial firing cable. There have been cases where such a fragment created a small gap between the conductor and braid causing the firing voltage discharge to breakdown and the detonator to misfire, even though the cable passed the open circuit/short circuit test. If any cables are repaired or replaced another functioning test will need to be performed.

7.2 Instrumentation Schematic

- An instrumentation schematic such as the simple example shown in Appendix A.19 is very useful in understanding the instrumentation requirements and how the firing system interfaces with other instrumentation. In addition, it's useful when selecting the equipment and cables required for the job and helps to ensure there are no omissions on set-up at the test site.

7.3 Checklist

- A checklist should be written and used for each job; a simple example is shown in Appendix A.21 and the actual checklist used in the 2.25 kg Explosive Test Facility is reproduced in Appendix E. A good checklist will ensure that operations are conducted in the appropriate order and that nothing is overlooked. As with instrumentation, a checklist needs to be tested and initially may need some refinement. When using a checklist, it is recommended that each item be physically checked, e.g. ticked with a pen, not just read.

7.4 Countdown and Communications

- In addition to prescribed warning signals (see 5.4) a countdown is generally required to warn those inside the firing facility. This may be a simple... "three, two, one, fire!"... to alert those present to the firing or it may be a longer countdown taking account of other instrumentation requirements, e.g. tape recorder up-to-speed time. For all but the simple cases it will be necessary to liaise with such people as instrumentation operators, Range (Field) Safety Officer or Range Firing Officer, to agree on an appropriate countdown. In the field there will often be personnel at more than one location, in which case it will be necessary to ensure adequate communications are provided (and tested) so that everyone is able to be checked undercover and to hear the countdown.

8. Summary

It can be seen from this document, that the Firing Officer or Firing Liaison Officer, has a number of important responsibilities (Appendix A.22). These include the preparation and safe operation of high-voltage firing equipment, explosive charge preparation, arming and firing the charge, interfacing with other instrumentation, liaison with other specialists, adherence to explosives and other safety procedures and explosives waste disposal. Furthermore a Firing Officer, who will typically be a Technical Officer Level 2 or 3 or a junior Professional Officer, is required to exercise a certain authority which importantly must have the backing of the Divisional line management.

Therefore a Firing Officer needs to be properly trained and possess a range of knowledge and skills, both technical and interpersonal, and considerable experience to properly perform the function. It will however sometimes be possible to train a person to perform restricted Firing Officer duties when conducting relatively straightforward explosive tests, such as the Small Scale and Large Scale Gap Tests [6, 7], where a lower level of knowledge and experience would be sufficient to safely conduct the tests. The information contained in this document, together with knowledge and experience of explosives and explosives handling, sound instrumentation skills and hands-on firing experience, should ensure that future Firing Officers are well trained and able to carry out their duties in a safe and effective manner.

9. Acknowledgements

John Pisani made a major contribution towards writing the Firing Procedures (Appendix C) and Checklists (Appendix E) for the Maribyrnong firing chambers. Phillip Box, David Hatt (referee), Trevor Kinsey (Chairman, ExSAP) and Ken Schebella made many constructive comments and suggestions which have been included in this document.

10. References

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2. Thorpe, B.W. (1996).
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Appendix A

Visual Aids to be used for Firing Officer Training

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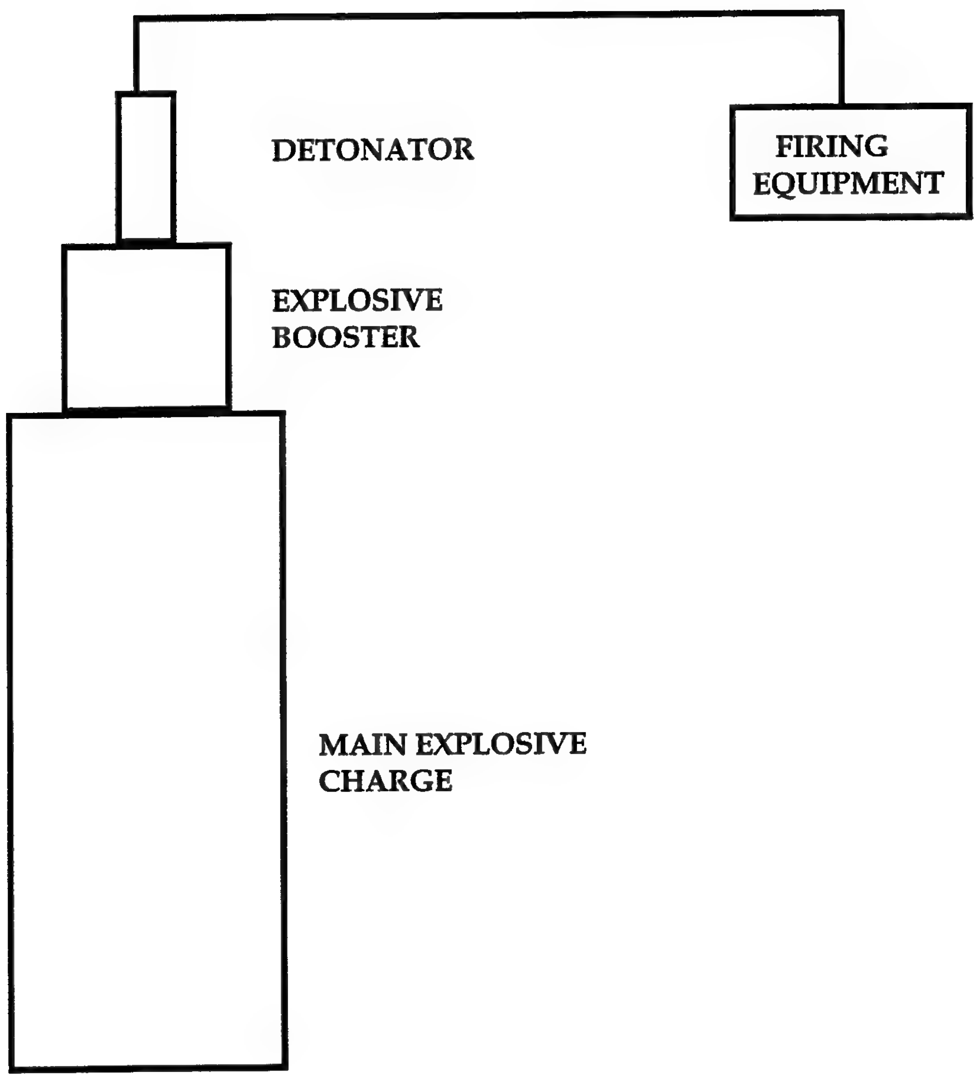
A.1 Explosive Firing: Basic Requirements



A.2 Electric Detonator [3]

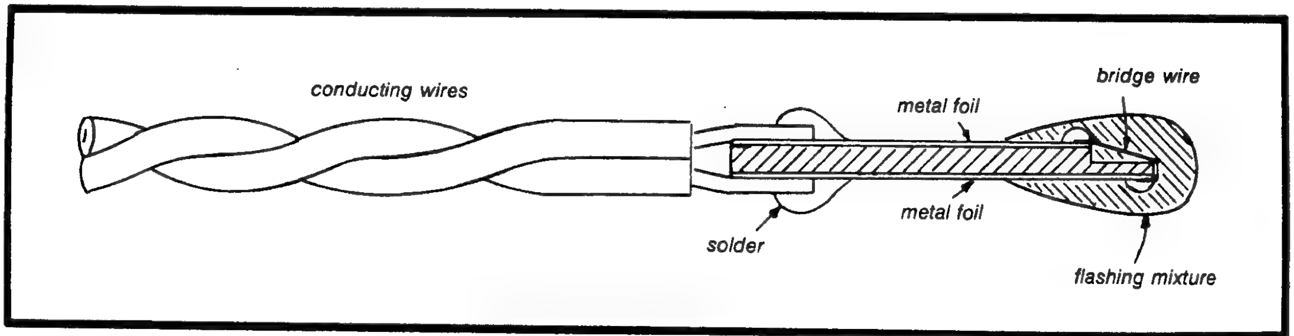


Fig. 1 Construction of an Electric Fusehead

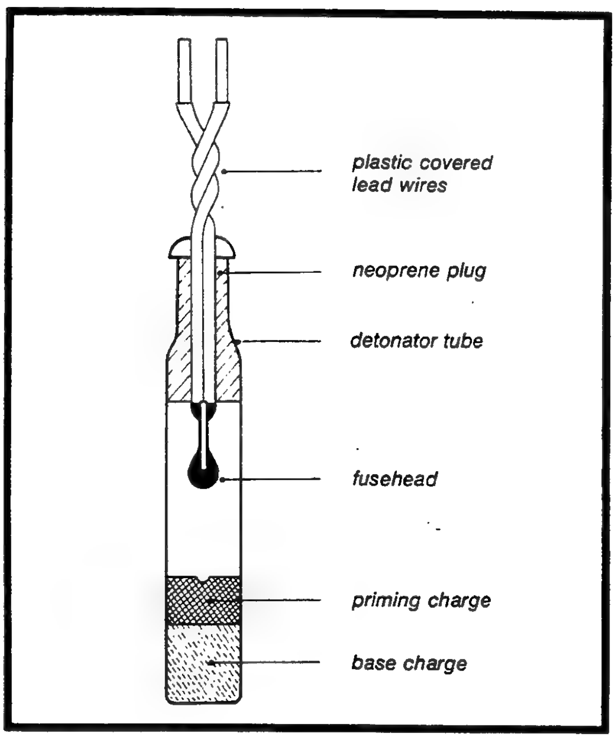
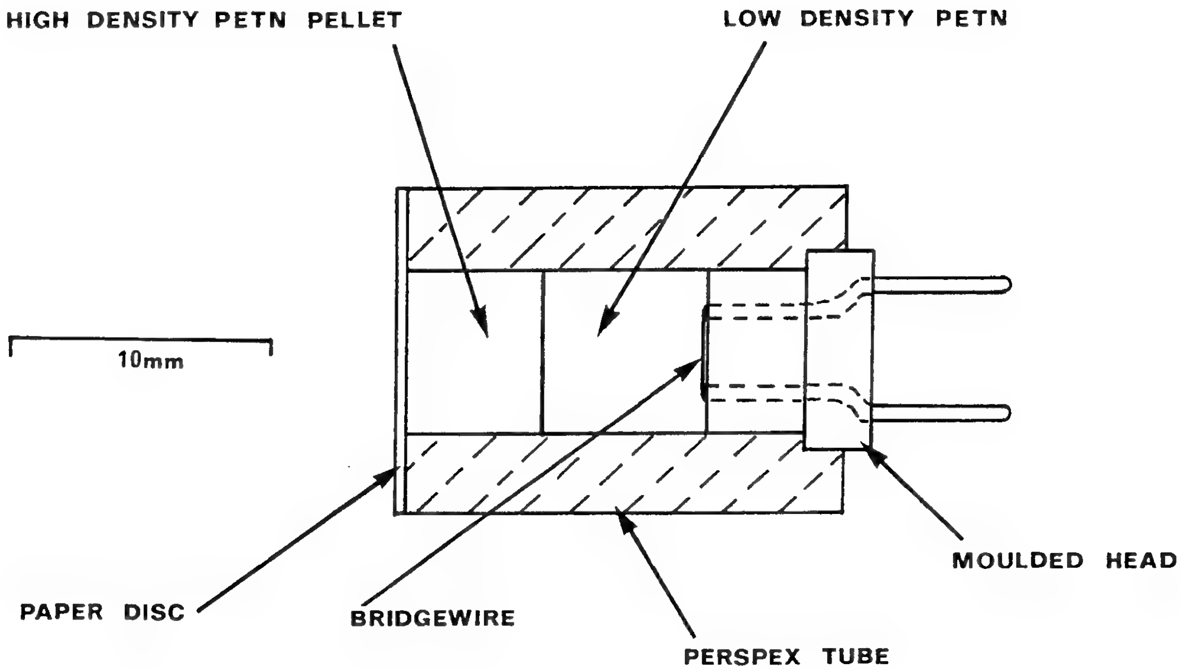


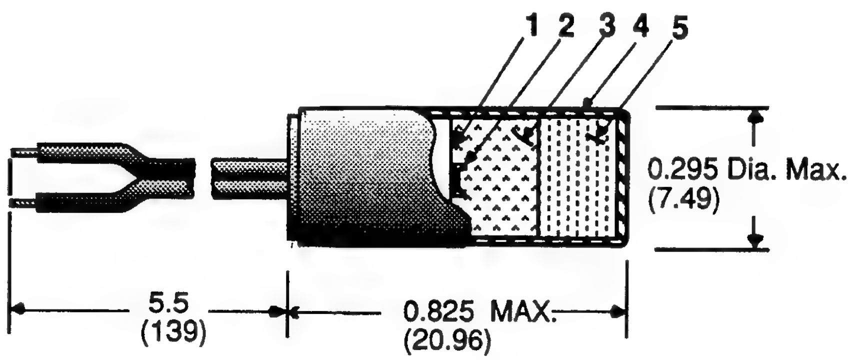
Fig. 2 Instantaneous Electric Detonator

A.3 EBW Detonator



A.4 RP-501 Economy Detonator [4]

The RP-501 is an EBW detonator for use in general purpose applications where the safety of secondary explosives is desired and where cost is a paramount consideration. There is a distinct trade-off between price and performance; therefore, the user should carefully examine the performance specification of this detonator before selecting it for an application. For the purpose of performance comparison refer to the RP-1 and RP-2 detonators which are also shown in this catalog. The RP-501 detonator is a standard, end lighting detonator capable of detonating compressed TNT and COMP C-4.



PARTS DESCRIPTION

1. MOLDED HEAD.
2. GOLD BRIDGEWIRE: 0.0015 inches in diameter, .040 inches long.
3. INITIATING EXPLOSIVE: 136 mg of PETN.
4. OUTPUT EXPLOSIVE: 227 mg of RDX with binder.
5. CUP: .007" thick aluminum.

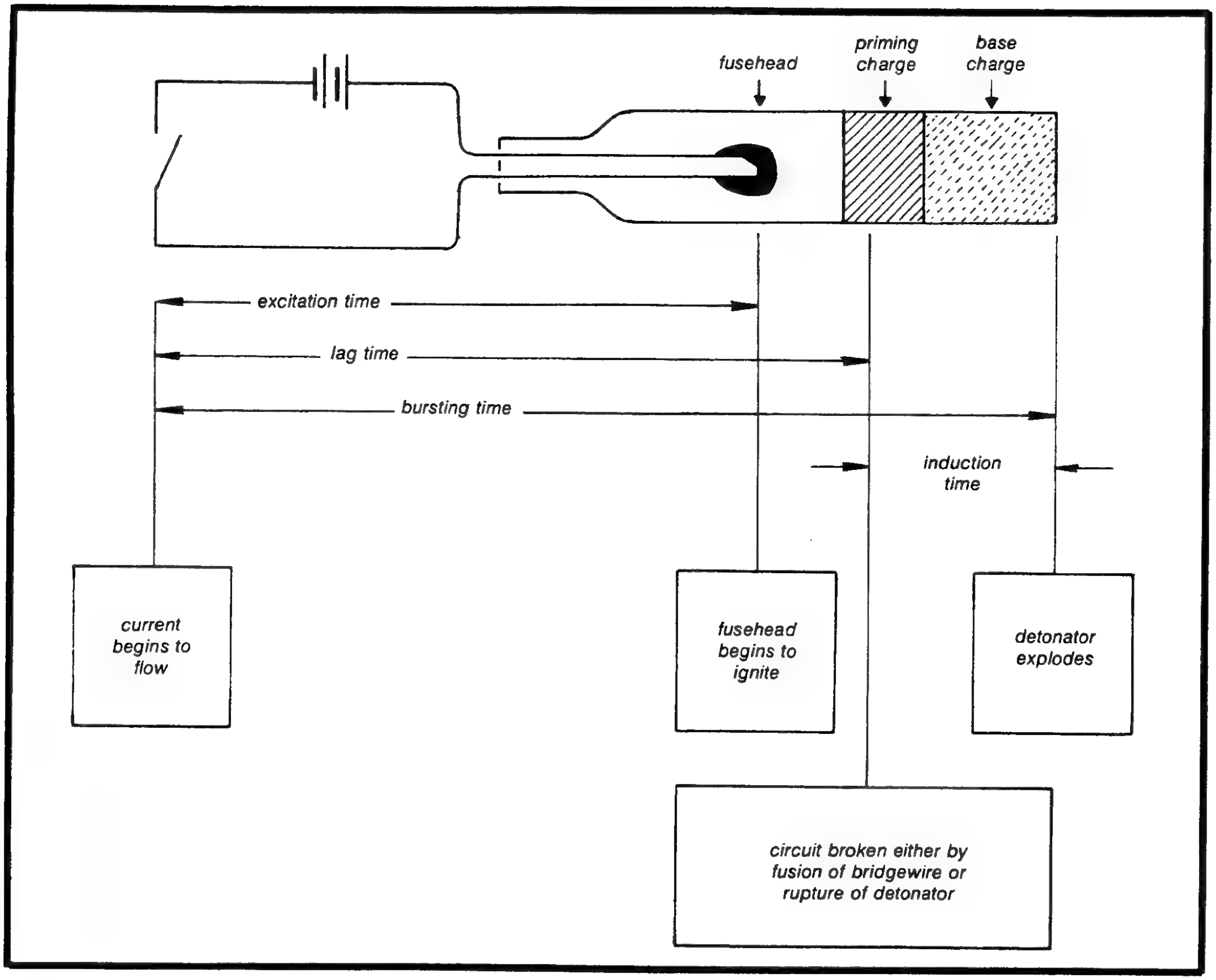
PERFORMANCE

- Threshold Burst Current (I_{bth}) .... 180 amps
- Threshold Voltage .... Approx. 500 volts
- Threshold Voltage Std. Deviation .... 75 volts maximum
- Function Time ....2.8 µs typical
- Function Time Simultaneity
  Standard Deviation ....0.500 µs max

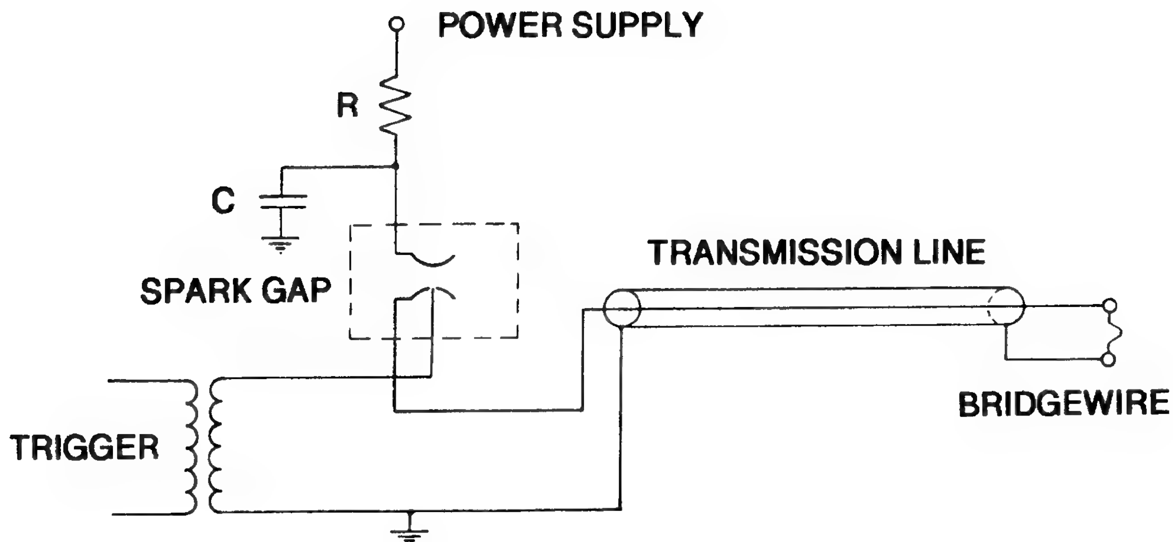
A.5 Comparison Between Electric And Exploding Bridgewire (EBW) Detonators

CHARACTERISTIC	ELECTRIC DETONATOR	EBW DETONATOR
Explosive Fill	Contains primaries, e.g. lead azide, lead styphnate	Contains only secondaries, e.g. PETN, RDX
Energy to Function	Low energy	Rapid high energy input
Mode of Initiation	Thermal, by electrical heating of bridgewire	Shock, by high energy discharge exploding the bridgewire
Functioning Time	Long and variable, 50 μs - 5 ms	Short and reproducible, <5 μs
Waterproof	Available	Available
RF Hazard	Possible	No
Static Discharge Hazard	Possible	No
Country of Origin	Australia	USA
Cost	$2.00 ea	$10 - $50 ea

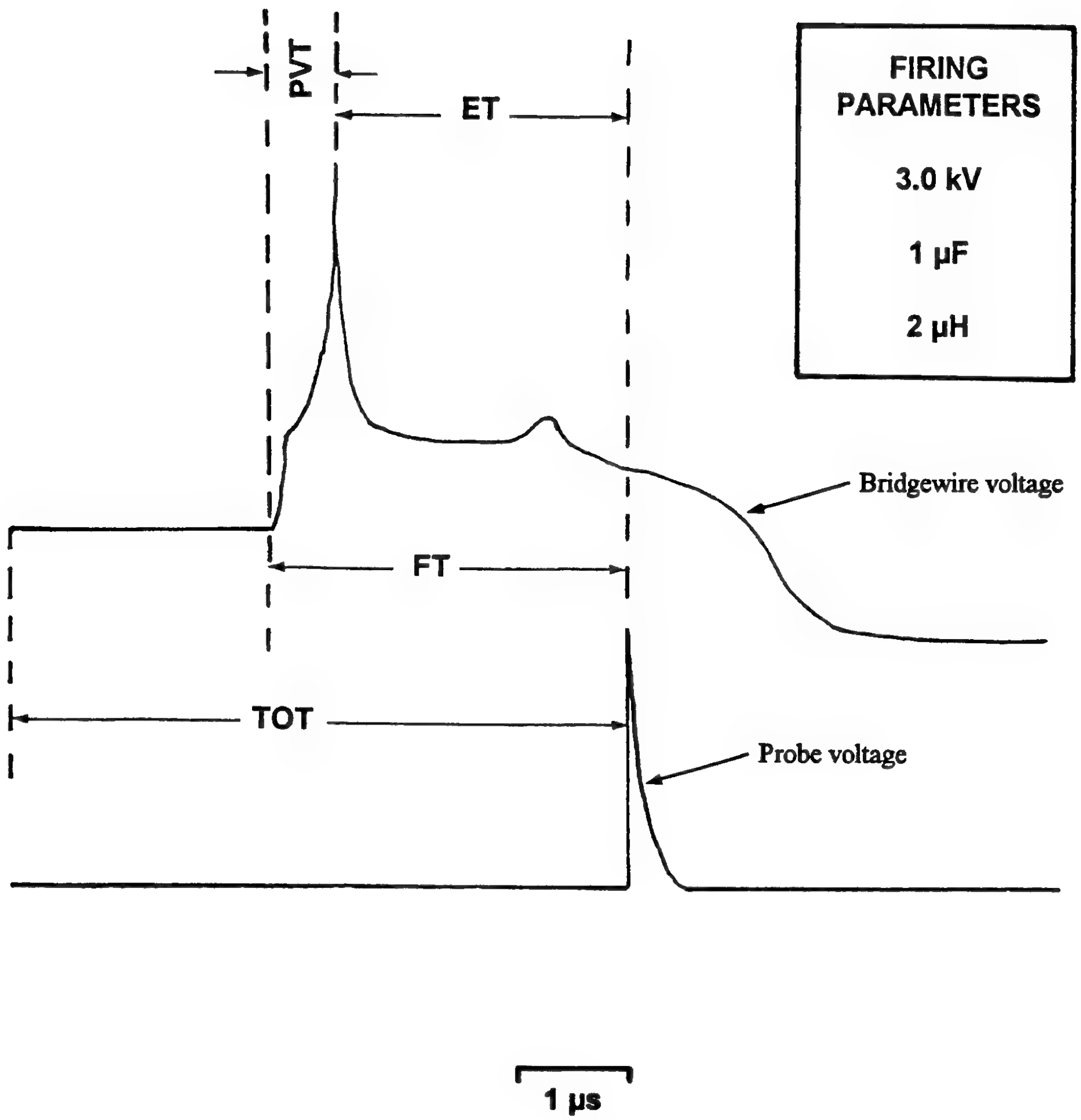
A.6 Electric Detonator Functioning Sequence [3]



A.7 EBW Detonator Basic Firing Circuit



A.8 EBW Detonator Functioning Characteristics



A.9 Exploding Bridgewire (EBW) Detonators

Advantages

SAFETY

- ONLY SECONDARY EXPLOSIVE (PETN, RDX)
- NOT EASY TO INITIATE - REQUIRES RAPID HIGH-VOLTAGE CAPACITOR DISCHARGE FOR INITIATION
- NOT SENSITIVE TO STATIC, RF OR ROUGH HANDLING
- CAN BE ATTACHED TO EXPLOSIVE CHARGE BEFORE CONNECTING FIRING LEAD (*WITH AN ELECTRIC DET FIRING LEAD MUST BE CONNECTED BEFORE ATTACHMENT TO CHARGE*)

SYNCHRONISATION

- SHORT REPRODUCIBLE FUNCTIONING TIME (< 5 μs) IS IDEAL FOR SYNCHRONISING WITH OTHER INSTRUMENTATION

Disadvantages

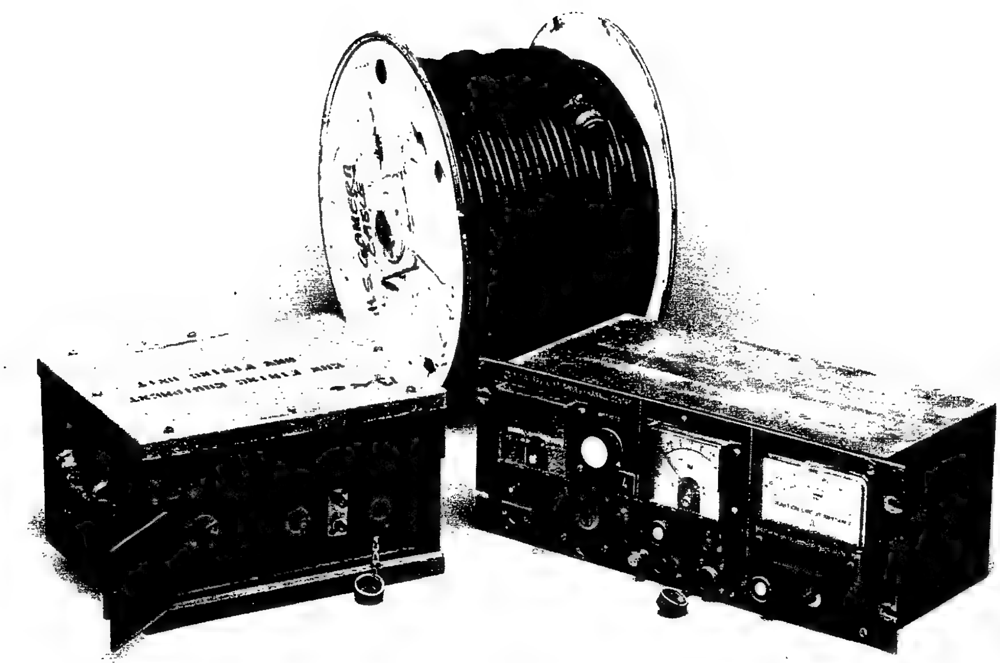
SPECIAL EQUIPMENT

- SPECIAL FIRING EQUIPMENT AND CONTROL CABLE REQUIRED
- FIRING UNIT MUST BE CLOSE TO EBW DETONATOR TO ACHIEVE LOW CIRCUIT INDUCTANCE

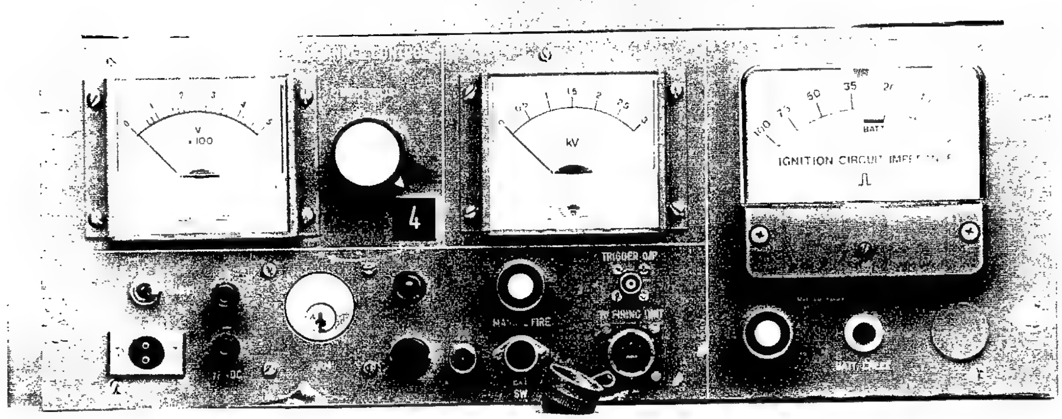
COST

- RELATIVELY EXPENSIVE ($10 - $50 ea)

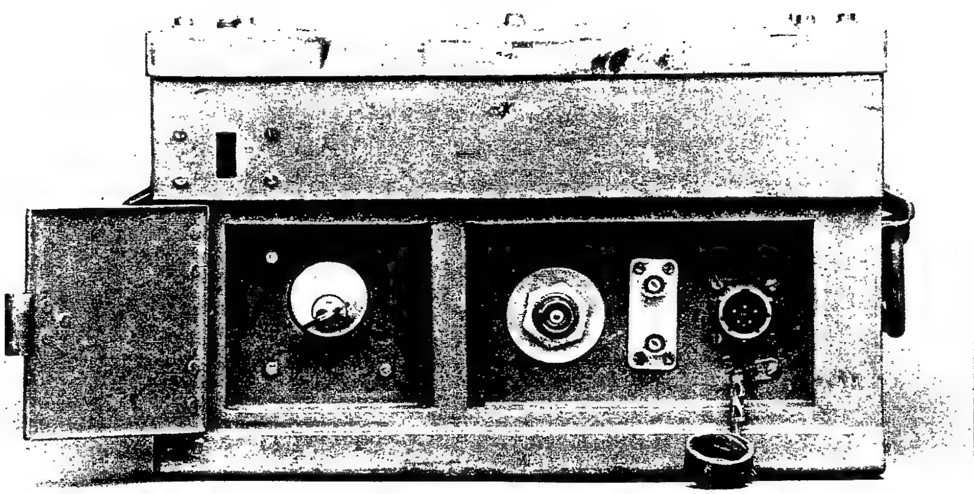
A.10 Photograph of EBW 3.0 kV Firing System for Field Use (L-R: Firing Unit, Control Cable and Control Unit)



A.11 Front Panel of EBW 3.0 kV Single Channel Control Unit



A.12 Front Panel of EBW 3.0 kV Firing Unit



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A.13 Brief Description of the AMRL EBW 3.0 kV Firing System

THE SYSTEM COMPRISES A **CONTROL UNIT**, A **FIRING UNIT** AND A **SAFE/ARM KEY**, WHICH MUST ALL HAVE THE SAME IDENTIFICATION NUMBER, AND **INTERCONNECTING CABLES.**

Control Unit

- IS CONNECTED TO THE FIRING UNIT BY A FIVE - CORE CONTROL CABLE AND A COAXIAL TRIGGER CABLE.
- IS SAFE UNTIL ARMED BY INSERTING THE SAFE/ ARM KEY IN THE KEY SWITCH AND TURNING IT CLOCKWISE.
- SUPPLIES AND MONITORS 240 VAC TO THE FIRING UNIT.
  THE CONTROL UNIT CAN BE POWERED BY THE MAINS SUPPLY OR A GENERATOR AND SELECTED CONTROL UNITS CAN BE POWERED BY A 12 V BATTERY.
- SUPPLIES BATTERY VOLTAGE FOR FIRING CIRCUIT CONTINUITY TEST AND DISPLAYS TOTAL CABLE/CIRCUIT RESISTANCE ON AN OHMMETER.
- MONITORS THE DC VOLTAGE ACROSS THE FIRING CAPACITOR AND DISPLAYS ON VOLTMETER (THE CAPACITOR AND A VOLTAGE DIVIDER ARE LOCATED IN THE FIRING UNIT).
- GENERATES A 150 V TRIGGER PULSE WHEN THE UNIT IS ARMED AND THE FIRING SWITCH IS PRESSED OR WHEN AN EXTERNAL SWITCH CLOSURE IS PROVIDED (e.g. FROM A HIGH-SPEED CAMERA).

A.14 Firing Unit

- ALSO CONTAINS A SAFE/ARM KEY SWITCH, KEYED - ALIKE WITH THE CONTROL UNIT SWITCH.

  WHEN THE KEY SWITCH IS IN THE SAFE POSITION (KEY TURNED CLOCKWISE) THE FIRING CAPACITOR IS SHORTED AND THE FIRING LEAD IS ISOLATED FROM THE FIRING CIRCUIT.

  AFTER CONNECTING THE DETONATOR, THE FIRING KEY IS TURNED ANTI - CLOCKWISE AND REMOVED AS THE SAME KEY IS REQUIRED TO ACTIVATE THE CONTROL UNIT. **AT THIS STAGE THE FIRING UNIT STILL CONTAINS NO STORED ENERGY!**

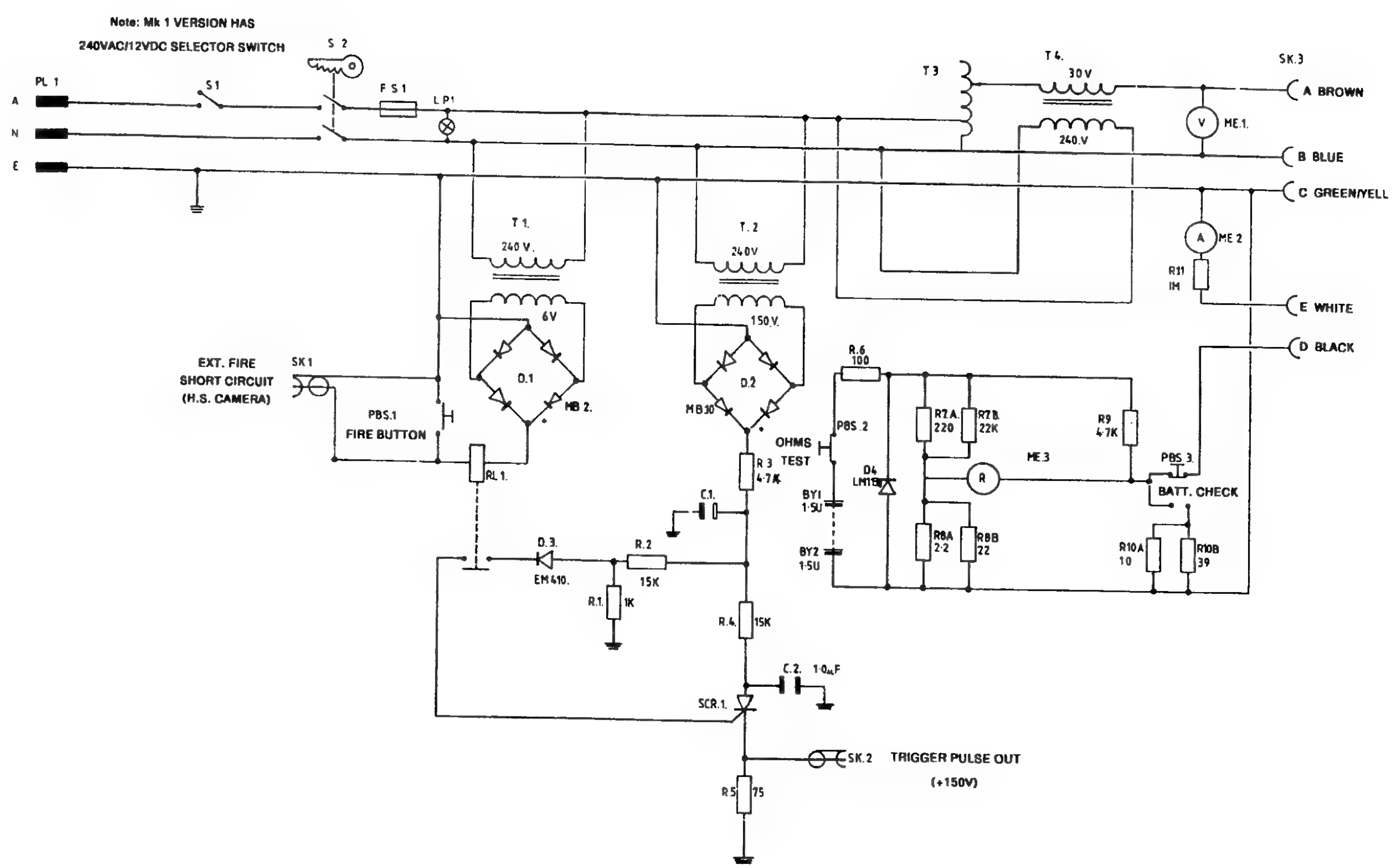
- STEPS UP AND RECTIFIES THE 240 VAC FROM THE CONTROL UNIT TO APPROX. 3 kV.
  DO NOT EXCEED 3.0 kV AS THE TRIGGERED SPARK GAP SWITCH IN THE FIRING UNIT HAS A NOMINAL STATIC BREAKDOWN VOLTAGE OF ONLY 3.3 kV.
  REACHING THE STATIC BREAKDOWN VOLTAGE WOULD CAUSE THE FIRING UNIT TO SELF - TRIGGER AND THE DETONATOR TO FIRE!

- CONTAINS A 1.0 μF CAPACITOR FOR FIRING PULSE GENERATION (THE FIRING CAPACITOR).

- RECEIVES A TRIGGER PULSE (FROM THE CONTROL UNIT OR OTHER SUITABLE PULSE GENERATOR) VIA THE COAXIAL CABLE WHICH FIRES AN SCR TRIGGER CIRCUIT WHICH IN TURN FIRES THE TRIGGERED SPARK GAP, DISCHARGING THE FIRING CAPACITOR ACROSS THE FIRING CABLE/EBW DETONATOR.

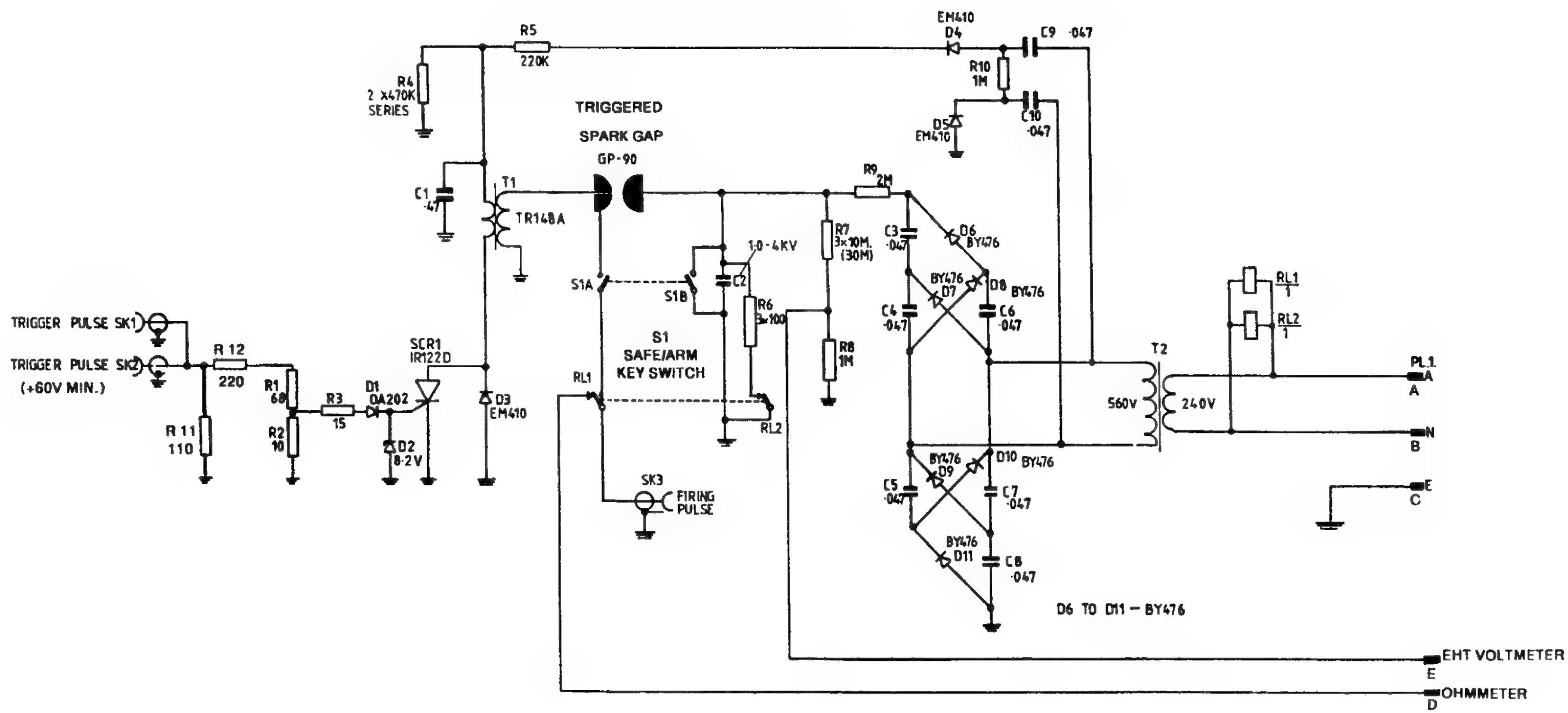
A.15 Single Channel Control Unit: Circuit Diagram

[Ref. Drawing MRL 3010-04, 1981-82]

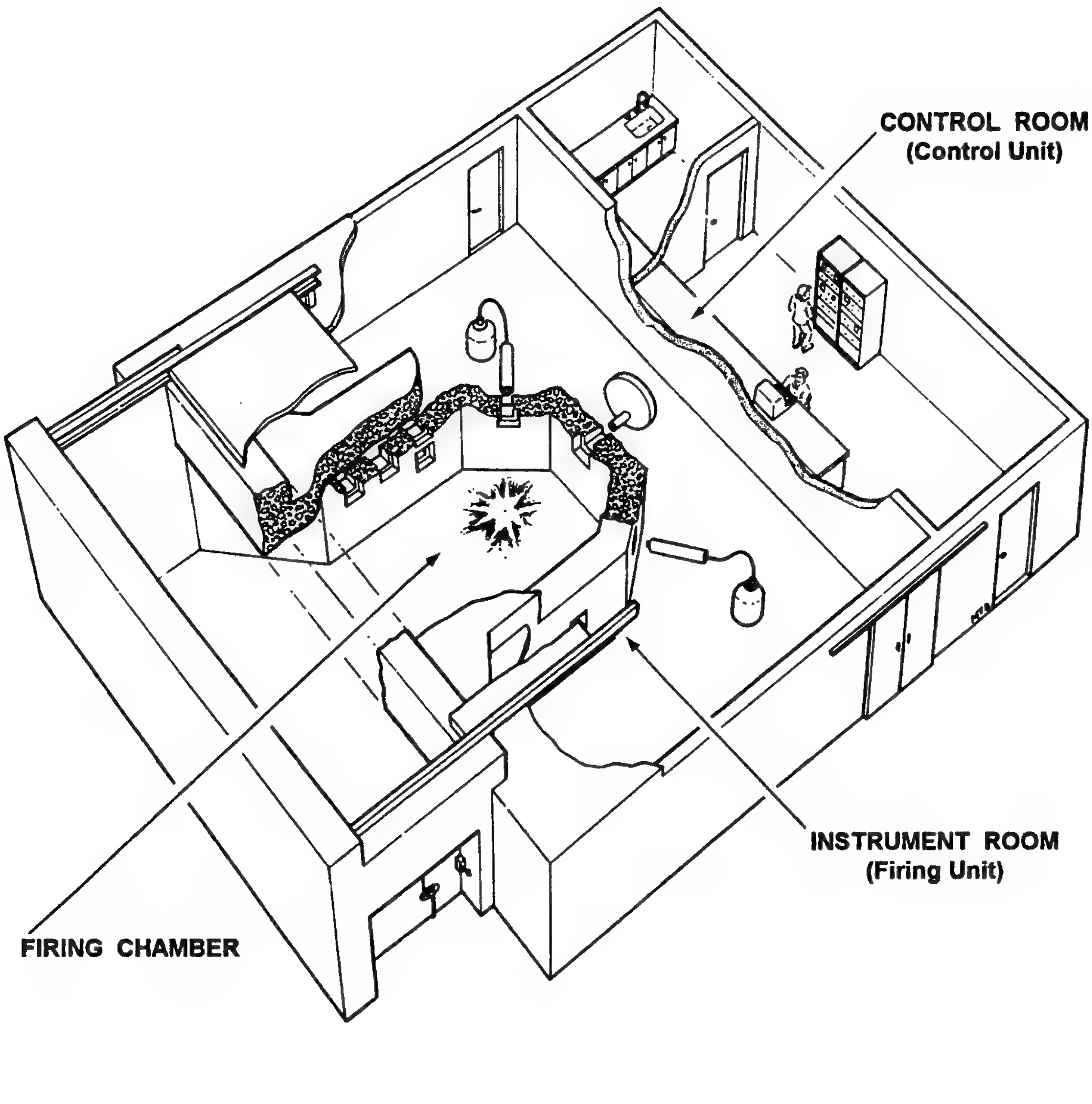


A.16 3.0 kV Firing Unit: Circuit Diagram

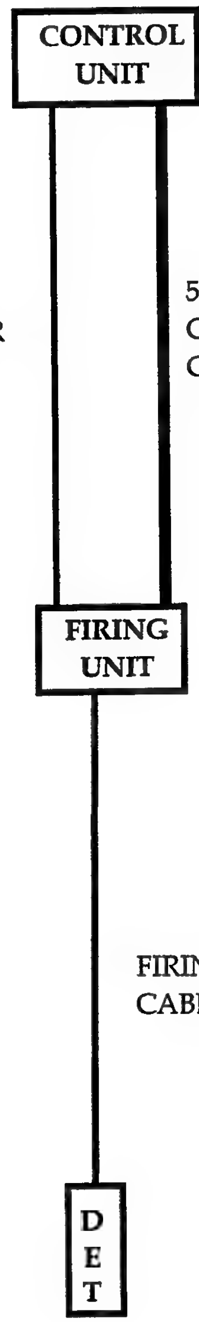
[Ref. Drawing MRL 3010-04, 1981-82]



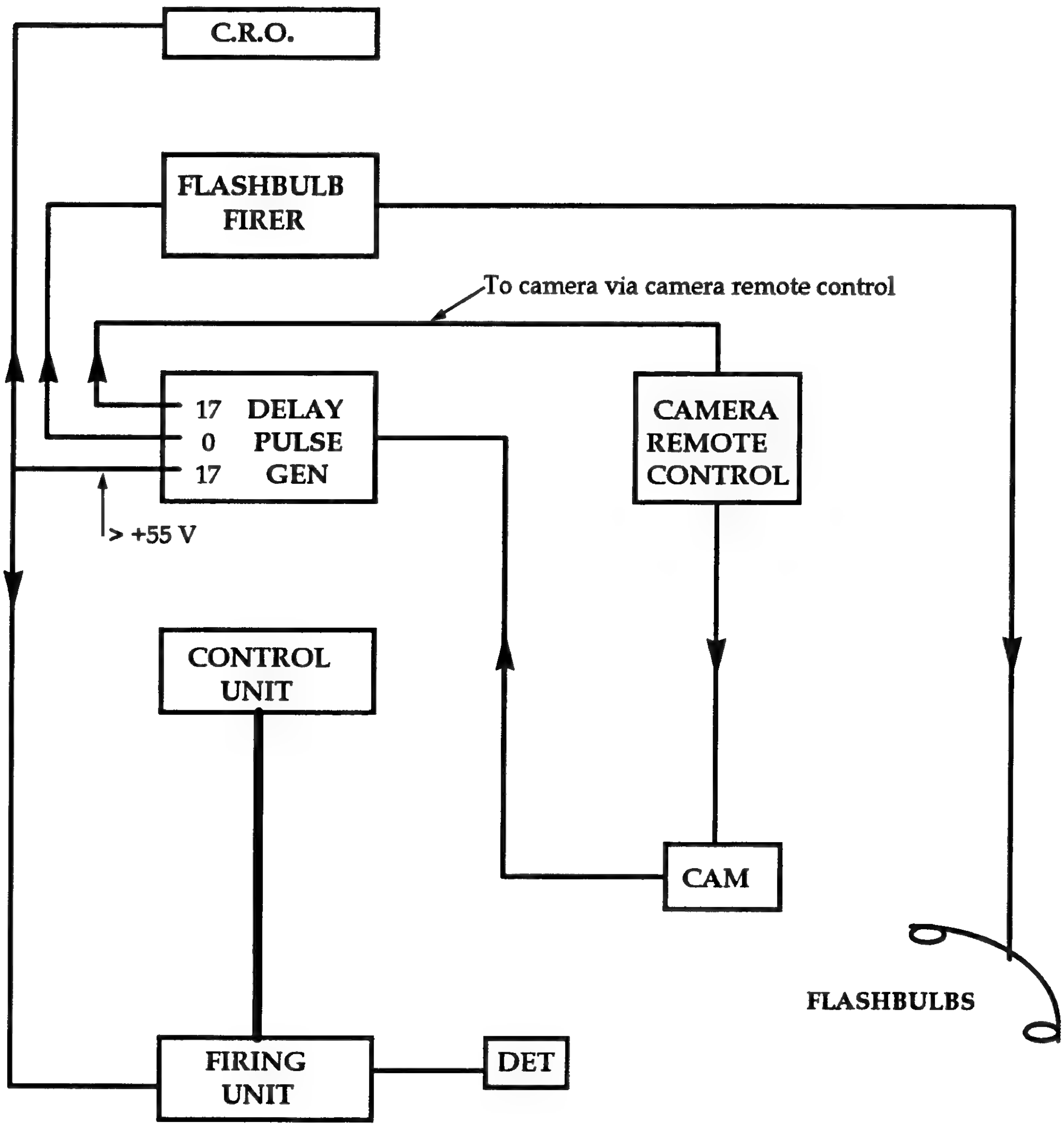
A.17 2.25 kg Explosive Test Facility



A.18 Schematic Of Basic EBW Field Firing System



A.19 Schematic of Typical Firing System with H.S. Camera where Firing Sequence is Initiated Externally



A.20 Some Good Practices for Firing Officers

FIRING EQUIPMENT

- TAKE SPARE SET
- SETUP AND TEST
- TEST WITH OTHER INSTRUMENTATION
- FUNCTIONING TEST AT START OF EACH DAY
- AFTER FIRING - CHECK FOR DAMAGE TO CABLES AND FIRING EQUIPMENT

INSTRUMENTATION SCHEMATIC

- IS VERY USEFUL IN UNDERSTANDING THE INSTRUMENTATION REQUIREMENTS AND DECIDING WHAT EQUIPMENT AND CABLES ARE NEEDED FOR THE JOB

CHECKLIST

- WRITE A CHECKLIST TO SUIT THE JOB

COUNTDOWN AND COMMUNICATIONS

- LIAISE WITH OTHERS INVOLVED (e.g. RANGE SAFETY OFFICER, CAMERA OPERATOR ETC) AND AGREE ON SUITABLE COUNTDOWN
- TEST COMMUNICATION LINKS AND ENSURE COUNTDOWN IS AUDIBLE

A.21 Typical Checklist for Firing System with High -Speed Camera

- CHECK TRIGGER COAX FROM H.S CAMERA IS OPEN CIRCUIT
- CHECK ALL CABLES ARE CONNECTED TO THE CONTROL UNIT
- CHECK THAT CAMERA REMOTE CONTROL IS SWITCHED **OFF**
- PERFORM OHMMETER BATTERY CHECK
- CHECK FIRING CIRCUIT RESISTANCE
- TURN **ON** CONTROL UNIT USING SAFE/ARM KEY AND **ADJUST VOLTAGE TO READ 3.0 kV** ON EHT METER
- WHEN READY START CAMERA BY SWITCHING **ON** REMOTE CONTROL
- OBSERVE DISCHARGE ON CONTROL UNIT EHT VOLTMETER
- AFTER APPROX 10 s TURN **OFF** CAMERA REMOTE CONTROL
- TURN **OFF** CONTROL UNIT AND REMOVE SAFE/ARM KEY
- DISCONNECT H.S. CAMERA TRIGGER COAX FROM CONTROL UNIT
- RECORD TIME OF FIRING

A.22 Some Firing Officer (Firing Liaison Officer) Responsibilities

- PREPARATION AND USE OF HIGH - VOLTAGE FIRING EQUIPMENT
- EXPLOSIVE CHARGE PREPARATION (SOMETIMES)
- ARMING THE CHARGE (CONNECTING THE DETONATOR)
- FIRING THE CHARGE
- INTERFACING WITH OTHER INSTRUMENTATION
- LIAISON WITH OTHER SPECIALISTS
- ADHERENCE TO SAFETY PROCEDURES (EXPLOSIVE, HIGH - VOLTAGE, RADIATION ETC)
- ENSURING THE PROPER DISPOSAL OF EXPLOSIVES WASTE GENERATED AS A RESULT OF CHARGE PREPARATION AND/OR FIRING

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Appendix B

Standing Safety Order for Building 1076 Explosive Test Facility

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STANDING SAFETY ORDER NO. 1076/1-3

BUILDING NO. 1076

TITLE 2¼ kg Explosive Test Facility

BUILDING HAZARD RATING HD 1.4

OFFICER-IN-CHARGE M.G.WOLFSON (EXT 8549)

PROCESSES

1. Firing Chamber
   Final assembly and firing of instrumented and non-instrumented explosive charges not exceeding 2¼ kg explosive mass (confined and unconfined).
2. Instrument Room
   No explosives processes permitted.
3. Control Room
   No explosives processes permitted.
4. Workshop
   No explosives processes permitted.

FLAMMABLE LIQUIDS LIMIT 1.0 litre (for cleaning purposes only)

EXPLOSIVE LIMITS Primary explosives not permitted except where Specific Instruction No. 13 is invoked.

(1) Firing Chamber	2¼ kg
(2) Instrument Room	No explosives permitted
(3) Control Room	No explosives permitted
(4) Workshop	No explosives permitted
(5) Storeroom	No explosives permitted

STAFF LIMITS

(1) Firing Chamber - 3 (Three)
(2) Instrument Room - 6 (Six) Total man limit for building - 8 (Eight)
(3) Control Room - 6 (Six)
Additional observers may be approved by the Officer in Charge

Submitted by..Scientist in Charge

Endorsed by..Explosives Safety Advisory Panel

Approved by..CWSD (Licensing Authority)

STANDING SAFETY ORDER NO. 1076/1-3

GENERAL INSTRUCTIONS

1. In the event of a civil emergency being declared by the Chief, Weapons Systems Division all Standing Safety Orders are suspended.

2. The instructions as given in AMRL Explosives Regulations must be observed together with any additional instructions given below or posted on the Process Instruction Board.

SPECIFIC INSTRUCTIONS

1. Approved eye protection shall be worn when performing or observing operations of a hazardous nature.

2.(a) No explosive waste shall be maintained in the building. Explosives waste and explosives contaminated waste shall be disposed of in the drums provided in Charge Preparation Room, Bay 4, Bldg 1076 (Ref. SSO No. 1076/4).

(b) Primary explosives waste shall be disposed of in a manner detailed in writing by OIC Bay 2 Bld 675.

3. Approved hearing protection shall be worn by all personnel during firings.

4. Work shall not be performed in this bay unless a second person is present or within earshot.

5. If firing operations or X-ray tests are intended, permission must be obtained from the Officer-in-Charge who will issue appropriate Firing/Safety Keys. The person to whom the Firing Key is issued is designated the Firing Officer.

6. A Safety Check List will be issued by the Officer-in-Charge to the Firing Officer and used for each firing.

7. The revolving red warning lights must be switched on when explosives are in the Firing Chamber.

8. When the red warning lights are switched on any person requiring access to the area must obtain permission from the Firing Officer or, if none is designated, the Officer-in-Charge.

9. Hazardous X-ray equipment may be in use in the building. When this is so, warning signs must be displayed and obeyed.

STANDING SAFETY ORDER NO. 1076/1-3

10. At least 30 seconds before firing a warning signal of 3 short blasts on the siren must be sounded. Immediately a firing is completed an all clear signal of a 3 second blast on the siren must be sounded.

11. The time of firing and explosive mass must be recorded after each shot in the log book provided.

12. The use of non-electric detonators containing primary explosives is not permitted.

13. The use of electric detonators containing primary explosives is not permitted unless written approval is obtained from the Scientist-in-Charge on each occasion.

SAFETY OF OPERATIONS

1. The Officer-in-Charge must satisfy himself that the proposed operations in the firing area are safe before issuing the firing key.

2. The Firing Officer is responsible for the adherence to Standing Orders and the instructions of the Officer-in-Charge, the safety of all operations in the building and the evacuation of the area before firing.

3. During firing the doors to the Firing Chamber and Instrument Room and all gates to the Firing Area must be locked and the keys must be in the possession of the Firing Officer. The Firing Area is defined as the fenced area which includes Buildings 1072, 1076 and Bay 10 of Building 671.

4. When flash X-ray and/or other hazardous equipment is being used the Firing Officer is responsible for checking with the operator to ensure the overall safety of operations. (Ref. copy of Safety Study and Radiation Safety Standing Order for Flash X-Ray Equipment posted on Operating Instructions board).

5. After firing, when flash X-ray equipment is being used, the Firing Officer will confirm with the X-ray operator that the X-ray equipment is in a safe condition before
re-opening the doors to the Instrument Room and Firing Chamber.

STANDING SAFETY ORDER NO 1076/1-3

6. All personnel except those remaining in the Control Room, or those with special approval from the OIC to remain in the Instrument Room, must leave the Firing Area (including the Firing Control and Charge Preparation Rooms Bldg 671 and Bldg 1072) before commencement of the firing sequence.

7. Bldg 1076 must be vacated before commencement of the firing sequence in Bldg 1072.

8. Sentries and/or additional warnings should be provided as considered necessary by the Officer in Charge.

MISFIRE PROCEDURE

If a misfire occurs the Officer-in-Charge must be notified and no personnel may enter or approach the Firing Chamber or Instrument Room without his permission.

A period of 15 minutes must elapse before entering the Firing Chamber to investigate the cause of a misfire. In the case of initiation experiments, e.g. gap tests, a failure of the donor will constitute a misfire but a failure of the receptor charge alone will not.

Appendix C

Firing Procedure for Building 1076 Firing Chamber

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FIRING PROCEDURE - BUILDING 1076 FIRING CHAMBER

FOR FIRINGS INITIATED BY EXPLODING BRIDGEWIRE DETONATORS ONLY

(To be read in conjunction with SSO Nos. 1076/1-3 and 1076/4, and Radiation Safety Standing Order No. 11D).

1. Before operations involving explosives are commenced, the OIC shall:

1.1. Ensure that the proposed operations are in accord with established safety principles for the area, and that any instrumentation to be used within the firing chamber is provided with a suitable means of isolation from electrical power.

1.2. Satisfy himself that the Firing Officer fully understands the nature of the proposed operations, the proper firing procedures, and his responsibilities.

1.3. Issue Castell key FC5 and the appropriate check list to the Firing Officer.

2. Before explosives are brought into the chamber the Firing Officer shall:

2.1. Have possession of Castell key FC5, and retain it on his person at all times except when the firing chamber door is secured.

2.2. See that instrumentation is set up and checked as far as possible without explosive charge.

2.3. Check that any instrumentation within the firing chamber is isolated from sources of electrical power, and take possession of any isolating keys or plugs.

2.4. Turn on warning lights and check functioning.

3. Before connecting the firing lead to the detonator the Firing Officer shall:

3.1. Check that Castell key FC5 and any other isolating keys/plugs are in his possession.

3.2. Lock double gates.

3.3. Lock Building 671 gates.

3.4. Check that all other gates to the firing area are locked.

3.5. Take possession of key to firing area gates.

3.6. Check that firing area is clear of all except authorised personnel.

3.7. Check that firing chamber ventilation shutters on both firing chamber ports are securely closed.

3.8. Check that all firing chamber viewing ports not in use are correctly blanked.

3.9. Check that no firing chamber viewing ports are uncovered.

3.10. Check that firing chamber is clear of tools and extraneous items.

3.11. Check that firing safety key is in firing unit and turned to "safe".

3.12. Check that FXR safety key is in FXR operator's possession (if FXR in use).

3.13. Direct all non essential personnel to leave firing chamber.

4. Firing procedure:

The Firing Officer shall:

4.1. Attach firing lead to detonator.

(The Firing Officer must have possession of Castell key FC5 and any other isolating keys/plugs and be personally present in the firing chamber from the time the firing lead is connected to the detonator until all other personnel have left the chamber).

4.2. Direct all personnel to leave chamber.

4.3. Secure firing chamber door (all 3 clamps must be secured) and take possession of Castell key H.

4.4. Check instrumentation bay readiness (liaise with FXR operator if FXR is being used).

4.5. Remove and take possession of firing safety key from firing unit.

4.6. Check that all personnel have left instrumentation bay.

4.7. Lock instrumentation bay and take possession of key.

4.8. Direct all personnel to enter and remain in control room until permission of the Firing Officer to leave is given.

(All personnel within the firing area, including the fragmentation pit and bay 10/671, must be accounted for).

(If there is any requirement for personnel to leave the control room after this stage, they must be accompanied by the Firing Officer, who must have possession of Castell key H and the FXR safety key (if FXR is in use)).

4.9. Check that indicator lights are showing:-

Firing chamber door closed.

Instrumentation bay doors closed.

4.10. Using Castell key H, unlock firing lead connector panel and connect firing control unit.

4.11. Check firing circuit continuity - if OK, proceed to step 4.13; if not, proceed to section 6.

4.12. Sound warning sirens - 3 blasts.

4.13. Insert firing safety key in firing control unit and turn to armed position.

4.14. Check EHT meter is reading 3.0 kV (EHT should not exceed 3.0 kV).

4.15. Check instrumentation readiness (liaise with instrumentation operators).

4.16. Direct all personnel to fit ear protection.

4.17. Give verbal count-down to "fire".

5. After firing - if firing successful.

The Firing Officer shall:

5.1 Sound all clear siren - one long blast.

5.2 Turn warning lights off (unless another firing is to be performed immediately).

5.3 Remove and take possession of firing safety key.

5.4 Disconnect firing control unit and take possession of Castell key H and any other isolating keys/plugs.

5.5 Enter firing details in log book.

5.6 If FXR in use, check that FXR system is safe and safety key in FXR operator's possession.

5.7 Unlock instrumentation bay.

5.8 Insert firing safety key in firing unit and turn to "safe".

5.9 Open the "in use" firing chamber ventilation shutter.

5.10 Unlock firing chamber and take possession of Castell key FC5.

5.11 Turn on firing chamber ventilation fan and allow fumes to clear.

5.12 Inspect firing chamber before other personnel are allowed to enter.

(Look for fire, unconsumed explosive, fumes and take remedial action as required).

5.13 Dispose of any contaminated waste in accord with approved procedures.

For further firings, provided that no gates to the firing area have been opened, operations shall commence at step 3.7.

6. If EBW continuity reading is abnormal

All personnel other than the Firing Officer shall remain in the control room.
The Firing Officer shall:

6.1. Remove and take possession of firing safety key.

6.2. Disconnect firing control unit and take possession of Castell key H and any other isolating keys/plugs.

6.3. If FXR in use, ensure that high voltage is discharged, and take possession of FXR safety key

6.4. Enter instrumentation bay, insert firing safety key in firing unit and turn to "safe".

6.5. If it is necessary to enter the firing chamber, take possession of Castell key FC5.

6.6. Investigate defect.

Report cause, and action taken, on firing check list.

(After correction of fault, operations shall re-commence at step 4.3).

7. If a misfire occurs:

All personnel other than the Firing Officer shall remain in the control room.

The firing chamber or instrumentation bay shall be opened only by the OIC, and only after the specified waiting time has elapsed.

The Firing Officer shall:

7.1 Record the time of the misfire on the check list.

7.2 Remove and take possession of the firing safety key.

7.3 Disconnect firing control unit and take possession of Castell key H and any other isolating keys/plugs.

7.4 If FXR in use, ensure that high voltage is discharged, and take possession of FXR safety key.

7.5 Notify Officer in Charge.(Open gate to admit OIC, and lock it after him).

7.6 After the specified waiting time, the misfire shall be investigated by the OIC.

If the problem is able to be rectified the firing procedure shall be repeated from step 4.3.

If the firing is abandoned, all explosives shall be rendered safe and returned to storage or disposed of.

8. **On completion of day's firings:**

8.1. Open the Bldg. 671 gates.

8.2. Return Castell key FC5 to the OIC.

8.3 Report any damage or defects in buildings or equipment to the OIC so that remedial action can be taken.

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Appendix D

Disposal of Explosives Waste: Safety Digest No 3

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DISPOSAL OF EXPLOSIVES WASTE

SAFETY DIGEST NO. 3 - D. SMITH

This note is a guide to the methods to be used in the E&A Composite (*now WSD-MB*) for disposal of the more common explosives and related wastes. For further advice on disposal of any particular wastes, please consult your Scientist-in-Charge.

Whenever explosives are handled in the laboratory, the following basic principles are a guide to the many details of good laboratory practice:-

(i) explosives should not be confined,

(ii) different classes of explosives should be segregated,

(iii) explosives should be kept free from any contamination, and

(iv) a high standard of housekeeping should be maintained at all times.

These principles apply equally well to the handling and disposal of waste explosives and materials contaminated with explosives. Explosives wastes however require particular care in handling since their properties (including sensitivity) will not be well characterised. It should be noted that wherever explosives waste can be conveniently destroyed chemically, this is the preferred option.

GENERAL

- NEVER dispose of explosives in a confined state.
- NEVER mix waste types except as allowed below
- NEVER allow glass, abrasives or hard or sharp objects, to be disposed of with bulk explosives.
- NEVER dispose of other materials in explosives waste drums.
- NEVER use other people's waste bins without permission.

DISPOSAL METHODS

Please note that primary explosives (other than rubbish contaminated with minute quantities of primary explosive) are not to be disposed of in <u>any</u> waste drums.
All laboratories where primary explosives are permitted <u>must</u> have specific disposal methods detailed in writing by Head EDU (*now OIC Bay 2 Bldg 675*). Disposal is by destruction, usually chemical, so that waste primary explosives are not allowed to leave the E&A (*now WSD-MB*) laboratories.

1. HE UNDER WATER (White drum black lettering)

This drum is for the disposal of solid high explosives. In laboratories where this is permitted, an appropriately coloured and labelled plastic drum will be provided, complete with a polythene liner bag and lid. Whenever possible the waste explosive should be placed into a small plastic bag, sufficient water added to cover the explosive, and the bag tied off by knotting or use of plastic- covered tie wire. Acidic solutions contaminated with HE should be diluted and disposed of in this drum.

2. RUBBISH CONTAMINATED WITH EXPLOSIVES (Black drum, white lettering)

This drum is used for materials such as rags, tissues, paper etc (i.e. 'soft' waste) which have been contaminated with small amounts of HE, pyrotechnics, or propellants. The waste may be disposed of dry, directly into the liner bag, except in the case of contaminated abrasive papers, which should first be placed in a small plastic bag and tied off. No bulk explosive, no primary explosive, and no hard materials such as glass or metal may be placed in this drum.

3. METAL CONTAMINATED WITH EXPLOSIVES (Yellow drum, Black lettering)

This drum is used for metal components contaminated with trace amounts only of HE, pyrotechnics, or propellant. Waste may be placed in a dry condition directly into the liner bag.

4. RUBBISH CONTAMINATED WITH PRIMARY EXPLOSIVES (Red drum, Black lettering)

This drum is used for the disposal of soft waste contaminated with trace amounts of primary explosives. Disposal is as for drum 2, except that abrasive materials contaminated with primary explosives must be treated chemically before disposal. No bulk explosive, and no hard materials such as glass or metal may be placed in this drum.

5. PYROTECHNICS UNDER OIL (Orange drum, black lettering)

This drum is used for the disposal of solid pyrotechnic waste. Disposal is as for drum 1, except that oil is used to cover the explosive instead of water. A supply of suitable oil is required to be kept in any laboratory where these waste drums are permitted.

6. PROPELLANTS UNDER WATER (Blue drum, black lettering)

This drum is for propellant waste, which is disposed of in an identical manner to HE: under water, packaged as for drum 1.

7. HE IN WASTE SOLVENT (Black drum, white lettering)

This drum is for waste solvents containing HE. The drum has a screw-top lid, and is used without a liner bag. Prior to use the drum should be filled at least one tenth with water. Solvents may then be added directly into the drum. No acids are permitted in this drum.

8. SPECIAL WASTE DRUMS (Green drum, black lettering)

From time to time drums will be required to suit special explosives waste needs, for example disposal of broken glass which cannot be decontaminated or other incompatible mixtures. Green drums will be made available for this purpose and must be labelled appropriately. Disposal methods must be established with the Scientist-in-Charge.

9. SPECIAL SOLVENT DRUMS (Small white drum, black lettering)

These drums are to be used for solvents contaminated by explosives other then HE. Drums must be labelled appropriately and disposal methods established with the Scientist-in-Charge.

10. RED PHOSPHORUS

Red phosphorus must never be allowed to come in contact with explosives or strong oxidants. Special precautions must be observed when handling or disposing of red phosphorus to ensure it is segregated from explosives. The written permission of Head E&A Composite *(now Research Leader Safety and Energetic Materials)* must be obtained before red phosphorus is handled in the explosive area, such instructions must include a method of disposal of waste.

E&A EXPLOSIVES SAFETY COMMITTEE *(now ExSAP)*

December 1981

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Appendix E

Firing Checklist for Building 1076 Firing Chamber

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FIRING CHECK LIST - BUILDING 1076 FIRING CHAMBER

FOR FIRINGS INITIATED BY EXPLODING BRIDGEWIRE DETONATORS ONLY

FIRING OFFICER______________________________DATE____________________

DESCRIPTION OF FIRING____

Reference to the Firing Procedure posted with the SSO is necessary when performing a firing with the aid of this check list.

BEFORE FIRING LEAD IS CONNECTED TO DETONATOR				
2.1, 2.3	CASTELL KEY "FC5" & OTHER ISOLATING KEYS/PLUGS IN FIRING OFFICER'S POSSESSION			
2.4	WARNING LIGHTS ON			
3.2 TO 3.6	FIRING AREA SECURED AND CLEAR OF ALL EXCEPT AUTHORISED PERSONNEL			
	NUMBER OF PERSONNEL WITHIN FIRING AREA (Including Frag. Pit and Bay 10/671) -			
3.7	FIRING CHAMBER VENTILATION SHUTTERS SECURED CLOSED			
3.8 TO 3.10	FIRING CHAMBER AND INSTRUMENTATION PROPERLY PREPARED			
3.11	FIRING SAFETY KEY IN FIRING UNIT AND TURNED TO "SAFE"			
3.12	FXR SAFETY KEY IN FXR OPERATOR'S POSSESSION (If FXR in use)			

FIRING				
4.2, 4.3	ALL PERSONNEL HAVE LEFT FIRING CHAMBER, DOOR SECURED AND CASTELL KEY "H" IN FIRING OFFICER'S POSSESSION			
4.6, 4.7	ALL PERSONNEL HAVE LEFT INSTRUMENTATION BAY, BAY LOCKED AND INSTRUMENTATION BAY KEY IN FIRING OFFICER'S POSSESSION			
4.8	ALL PERSONNEL DIRECTED TO ENTER AND REMAIN IN CONTROL ROOM UNTIL PERMISSION OF THE FIRING OFFICER TO LEAVE IS GIVEN			
	NUMBER OF PERSONNEL PRESENT IN CONTROL ROOM - - - - - - - - - -			
4.9	INDICATOR LIGHTS SHOWING CORRECT CONDITIONS			
4.11	FIRING CIRCUIT CONTINUITY OK (IF ABNORMAL GO TO 6.1)			
4.12	WARNING SIRENS - 3 BLASTS			
4.14	EHT SUPPLY OK			
4.15	INSTRUMENTATION READINESS CHECKED (Liaise with instrumentation operators)			
4.16	EAR PROTECTION FITTED			
4.17	VERBAL COUNTDOWN TO "FIRE"			

AFTER FIRING - IF FIRING SUCCESSFUL				
5.1	ALL CLEAR SIREN - ONE LONG BLAST			
5.2	WARNING LIGHTS OFF			
5.6	IF FXR IN USE, FXR SYSTEM SAFE AND SAFETY KEY IN FXR OPERATOR'S POSSESSION			
5.8	FIRING SAFETY KEY INSERTED IN FIRING UNIT AND TURNED TO "SAFE"			
5.9	FIRING CHAMBER VENTILATION SHUTTER OPENED			
5.10	FIRING CHAMBER UNLOCKED, CASTELL KEY "FC5" AND ANY OTHER ISOLATING KEYS/PLUGS IN FIRING OFFICER'S POSSESSION			
5.11, 5.12	FIRING CHAMBER INSPECTED AND CLEAR OF FUMES BEFORE OTHER PERSONNEL ARE ALLOWED TO ENTER			
5.13	CONTAMINATED WASTE DISPOSED OF IN ACCORD WITH APPROVED PROCEDURES			
IF EBW CONTINUITY READING IS ABNORMAL				
6.1	FIRING SAFETY KEY REMOVED AND IN FIRING OFFICER'S POSSESSION			
6.2	FIRING CONTROL UNIT DISCONNECTED, CASTELL KEY "H" AND ANY OTHER ISOLATING KEYS/PLUGS IN FIRING OFFICER'S POSSESSION			
6.3	IF FXR IN USE, HIGH VOLTAGE DISCHARGED AND FXR SAFETY KEY IN FIRING OFFICER'S POSSESSION			
6.4	FIRING SAFETY KEY INSERTED IN FIRING UNIT AND TURNED TO "SAFE" . CASTELL KEY "FC5" IN FIRING OFFICER'S POSSESSION IF CHAMBER ENTERED			
6.6	DEFECT INVESTIGATED - CAUSE: (eg open circuit EBW or firing lead, short circuit) ACTION TAKEN TO RECTIFY: (contact OIC if necessary)			
IF A MISFIRE OCCURS				
7.1	TIME OF FIRING ATTEMPT -----------------------			
7.2	FIRING SAFETY KEY REMOVED AND IN FIRING OFFICER'S POSSESSION			
7.3	FIRING CONTROL UNIT DISCONNECTED, CASTELL KEY "H" AND ANY OTHER ISOLATING KEYS/PLUGS IN FIRING OFFICER'S POSSESSION			
7.4	IF FXR IN USE, HIGH VOLTAGE DISCHARGED AND FXR SAFETY KEY IN FIRING OFFICER'S POSSESSION			
7.5	OFFICER IN CHARGE NOTIFIED - TIME -----------------			
7.6	WAITING TIME ELAPSED			
	MISFIRE INVESTIGATED BY OIC - CAUSE:			
OR	PROBLEM RECTIFIED AND FIRING ATTEMPT REPEATED			
	EXPLOSIVES RENDERED SAFE AND RETURNED TO STORAGE/DISPOSED OF			

RETURN THIS CHECK LIST TO THE OIC WITH THE CASTELL KEY FC 5.

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A Guide to Explosives Firing
Michael G. Wolfson

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19. ABSTRACT
This document is a guide to explosives firing using exploding bridgewire (EBW) detonators. It details the special equipment and procedures developed in the Weapons Systems Division, Maribyrnong and currently in use in the Division's firing chambers and at field test sites, and discusses the relative merits of electric detonators and EBW detonators. It serves as a useful guide and reference document to both Firing Officer trainers and trainees.

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